# APPENDIX C

# PHYSIOGRAPHIC DESCRIPTION OF THE SP-G1 AND SP-G2 STUDY AREAS

**NOTE: See Interim Report for SP-G2**
**For text of Appendix C**

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## PHYSIOGRAPHIC DESCRIPTION OF THE SPG-1 AND SPG-2 STUDY AREAS

## INTRODUCTION

This report documents the physiographic conditions of the SPG-1 and SPG-2 study areas. The watershed above Oroville Reservoir drains an area of 3,611 square miles (DWR, 1993). The North Fork and Middle Fork Feather Rivers comprise 3,222 square miles of this area, including portions of the foothill and mountain regions of the northern Sierra Nevada and southern Cascade Range. The South Fork and the West Branch comprise the additional 389 miles.

**Feather River Watershed Areas**

| Watershed | Area (square miles)* |
|---|---|
| North Fork@Pulga | 1,953 |
| Middle Fork nr. Merrimac | 1,062 |
| South Fork | 132 |
| West Branch nr. Paradise | 113 |
| Lake Oroville nr. Oroville | 3,607 |

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The upper Feather River watershed is producing unnaturally high sediment yields. High sediment yields are caused by accelerated erosion along tributaries and main trunks of the Upper Feather River system. A U.S. Soil Conservation Service report, *East Branch North Fork Feather River Erosion Inventory Report* (1989), estimated that ninety percent of erosion in a 1,209 square mile study area was accelerated erosion. Accelerated erosion is a soil loss rate greater than soil loss occurring under natural geologic conditions and is caused by such human activities as road building, timber harvesting, overgrazing livestock, and agriculture. High sediment yield can reduce reservoir capacity, degrade water quality, and harm fish and wildlife. High sediment yields have significantly impaired storage capacity and hydroelectric operations in several reservoirs upstream of Lake Oroville on the North Fork Feather River.

A large amount of sediment is captured by reservoirs upstream of Lake Oroville. Lake Oroville captures most of the remaining sediment moving down from the watershed. The amount of sediment has been estimated by several studies and is in the neighborhood of about 500 acre-feet per year. This in turn results in a sediment-starved river system below the dam. It is estimated that the trap efficiency of the reservoir is about 97 percent. A portion of silt and clay is discharged to the Feather River below the dam, but no pebbles, gravel, or cobbles. High flows discharging from the dam have scoured the streambed, resulting in coarsening and armoring of salmon spawning riffles as far downstream as Honcut Creek.

Prior to the 1850s, resource use in the watershed was limited. Local Native Americans lived in the area and hunted and fished. Their activities did little to change the natural environment although they were known to use fire to clear forest areas. Major resource use began in the watershed in the 1850s, and included livestock grazing, road building, timber harvesting, mining, and farming. Recent activities include local urban development and varied recreational uses. Beneficial uses of water include habitat for resident fish, recreation, hydroelectric generation, agriculture, and domestic supply.

The physiography and ecology are complex and sensitive to human activities. Complexity is caused by variation in elevation, slope and aspect, geology, soils, hydrology, climate, fire history, vegetation, and land use. These factors are inter-related and complex. For example, topography influences precipitation, thereby affecting vegetation, which in turn affects geomorphology and basin hydrologic characteristics.

## Department of Water Resources Facilities

The Department of Water Resources operates four reservoirs in the watershed (Table 2). Three facilities are in the upper watershed. Lake Oroville is the principal feature. Lake Oroville facilities also include the Thermalito Diversion Pool, the Thermalito Forebay (11,400 acre-feet), and the Thermalito Afterbay (61,100 acre-feet).

**Table of Department of Water Resources Reservoirs**

| **Reservoir** | **Storage (acre feet)** | **Location** |
|---|---|---|
| Antelope Lake | 22,570 | North Fork Feather<br>Indian Creek |
| Frenchman Lake | 55,480 | Middle Fork Feather<br>Little Last Chance Creek |
| Lake Davis | 84,370 | Middle Fork Feather<br>Grizzly Creek |
| Lake Oroville | 3,537,580 | Main Feather nr. Oroville |

Additionally, numerous large and small reservoirs owned by other entities are used for hydroelectric power generation, municipal water supply, recreation, and agriculture. The largest of these is Lake Almanor, owned by Pacific Gas and Electric Company.

## CLIMATE

The Feather River basin has a Mediterranean type climate with hot, dry summers and cool wet winters. Dominating and controlling the weather of northern California is the semi-permanent, high pressure area of the mid-Pacific Ocean. This pressure center moves northward in summer, pushing storm tracks well to the north. In winter, it generally moves south, allowing storms to cross California. Frontal cyclonic storms generally occur from November through March. Rainfall in the watershed is shown on the isohyetal map.

Rainfall within the watershed varies greatly because of topography and rain-shadow effects. The western part of the watershed intercepts winter moisture-laden air from the Pacific Ocean. Orographic effects result in an average increase of two to six inches for each 300-foot rise in elevation. Precipitation ranges from about 50 inches at Lake Oroville to 90 inches in the high mountains overlooking the Lake and in the upper end of the North Fork Feather River.

Rain-shadow effects limit precipitation within the southeastern part of the watershed. This is drained by the Middle Fork Feather River. Annual precipitation varies from 15 to 40 and averages about 30 inches within the shadow area.

About 50 percent of the precipitation occurs as snow, providing streamflow during the months of April, May, and June.

Many reservoirs occur in the watershed. Two of these have a major effect on streamflow. Lake Almanor controls flows in the upper part of the North Fork. Lake Oroville and appurtenant structures impounds the North, West Branch of the North Fork, Middle, and South Fork Feather River near the town of Oroville.

## TOPOGRAPHY

The Feather River watershed is complex, with numerous geologic formations, deeply incised canyons, broad alluvial valleys, many volcanic features, and steep forested slopes. The west-flowing upper Feather River system is unique because it is the only river which crosses the crest of the Sierra Nevada.

The watershed above Lake Oroville can be divided into a western and eastern topographic area. This designation is used frequently by Plumas National Forest and refers to areas west and east of the Sierra Nevada crest. The two areas differ in topography, climate, vegetative communities, and forest productivity.

The western topographic area comprises the western slope of the Sierra Nevada, bounded on the west by the Sacramento Valley and in the east by the Sierran crest. The western slope averages about 50 miles wide, east to west, and consists of mountainous terrain incised by south-west trending, steep-sloped canyons with depths exceeding 3,000 feet. Narrow plateaus of moderate relief are located between the canyons and are the most productive timber land. The western slope rises on a 4 degree inclination from the Sacramento Valley to the crest. Maximum elevations along the crest range from about 7,000 to 7,500 feet.

The eastern topographic area is bounded by the Sierran crest on the west and the Honey Lake escarpment on the east. It is characterized by northwest-trending, fault-bounded mountains separated by down-thrown alluvial valleys. These parallel features are similar to those of the adjoining Basin and Range geomorphic province. Valley bottoms are typically open with broad meadows and grass land used for livestock grazing and agriculture. Under natural conditions, streams in these valleys maintain gentle gradients because they have shallow banks, considerable riparian vegetation and a tendency to meander. Elevations range in this zone from 2,100 to 7,700 feet.

Below Lake Oroville, the Feather River emerges from the Sierra Nevada Mountains and enters the Sacramento Valley. Here the stream gradient is less and the topography subdued. The topography is mostly flat, with the exception of overflow channels, multiple channel areas, and both artificial and natural leeves occuring along the river course. Honcut Creek, the Yuba River, and the Bear River join the Feather before entering the Sacramento River at Verona. Elevation of the valley floor varies from about 150 feet at Oroville to about 25 feet at Verona.

## BASIN MORPHOLOGY

The North Fork basin is roughly triangular shaped, oriented in the east-west direction with a point of the triangle meeting the confluence of the Middle Fork in Lake Oroville. The basin's maximum length and width are 65 and 75 miles respectively. The widest segment of the watershed is along the Honey Lake escarpment on the northeast side. The East Branch North Fork Feather River is a major tributary. East Branch drains high elevation valleys and joins with the North Fork near Belden on Highway 70.

The Middle Fork basin is roughly crescent shaped. It is elongated along an east-west axis with its maximum length and width approximately 75 and 35 miles respectively.

The South Fork is much smaller. It skirts the southwest portion of the Feather River Watershed and mostly drains the lower foothills of the Sierra Nevada. The West Branch is also small with 113 square miles of area at the gage near Paradise.

The lower two-thirds of the Feather River watershed, both the Middle and North forks flow in deeply incised canyons with little or no floodplain. In the upper one-third, streams historically flowed in shallow meandering channels with broad floodplains covered with riparian vegetation. Floodwaters would quickly overtop the banks and deposit sediment on the valley floor. Under present conditions, land use changes have caused many of the headwater streams to loose their meander patterns and form into sharp V-shaped channels devoid of vegetation. The tall alluvial banks along these channels are easily eroded.

Sierra Valley, in the eastern portion of the Middle Fork watershed, is the largest basin (203 square miles) in the study area. Its shape is roughly circular, with smooth relief and is crossed by many weakly entrenched, meandering and braided streams.

## VEGETATION AND LAND USE

Vegetation is generally dependent on elevation, temperature and precipitation and also varies according to slope, aspect, soils, fire history and land use practices. Chaparral plants such as ceonothus, manzanita, chamise, oak species and digger pine grow at elevations below 2,000 feet. Mixed conifer forests containing Jeffrey pine, ponderosa pine, Douglas fir, incense cedar, white fir, red fir, and sugar pine grow at higher elevations. Elevation provides a general control of vegetation type but some plants such as manzanita and oak occur over a wide range.

Three roughly parallel vegetation areas, called "life zones", occur from the Sacramento Valley to the Sierran crest. From west to east, these zones are the Upper Sonoran life zone, Transition life zone and Canadian life zone (DWR, 1988). These are repeated on the eastern slope of the Sierras. The life zone classification is a generalized vegetation guide. Overlapping of species is common, depending on local conditions of elevation, moisture, soil, and others. For example, variation exists between vegetation on west-, north-, south-, and east-facing slopes because of the differences in topography, soils and moisture. Plant communities are often affected by past or present land use, particularly when certain species predominate in areas that have been burned or disturbed.

The lower Feather River between Verona and Oroville are in the Great Valley Riparian Forest environmental setting. The predominant forest type on the high floodplain is the Great Valley Oak Riparian Forest, surviving in small patches between agricultural development. The dominant tree specie is the valley oak. Great Valley Mixed and Great Valley Cottonwood riparian forests occur on lower, more recent river meander deposits. Dominant tree species include Freemont cottonwood, sycamore, box elder, and black walnut. Point bar deposits and lower stream banks are the home of the Great Valley Riparian Scrub community, dominated by the narrowleaf willow series.

The Upper Sonoran life zone begins in the foothills above the valley floor. The Upper Sonoran life zone is also called foothill woodland. The primary component of this community is the blue oak, with buckeye, digger pine, valley oak, and interior live oak also characteristic of this zone. This plant community dominates the western foothills and ridges between approximate elevations of 300 and 1,200 feet.

The Transition life zone is a broad transitional area between the foothill communities and the mixed conifers of the higher elevations. It dominates the elevations between 1,200 and 5,500 feet and contains a large variety of characteristic trees and shrubs. These include big leaf maple, canyon oak, black oak, interior live oak, madrone, ponderosa pine, sugar pine, white fir, Douglas fir, incense cedar, snow brush, deer brush, buck brush, manzanita, and poison oak.

The Canadian life zone occupies higher elevations, generally above 5,500 feet. This plant community is dominated by red fir and lodgepole pine but contains several other characteristic trees and shrubs including white fir, western white pine, sugar pine, western hemlock, greenleaf manzanita, bush chinquapin, coyote brush, bitter cherry, and snow brush.

Other plant communities exist in the watershed, which are more a function of soil and moisture than of elevation, including montane meadow, riparian zone, and sagebrush steppe.

Meadows exist in the alluvial valleys along major and minor tributary streams. These relatively flat meadow areas are floodplains, or "stringer" meadows, which are narrow strips along riparian areas, near seeps or springs. Meadows provide food and cover for wildlife and pasture for livestock. Characteristic vegetation is dense growth of sedges and other perennial herbs. Vegetative composition varies depending on the amount of moisture available. Soils are characterized by sandy loam and loamy sand, with a weak, fine granular structure. Without plant roots to hold them together, these soils are easily eroded (USFS, 1989).

The riparian zone includes aquatic ecosystems and distinctive vegetative communities that require a shallow ground water table. Periodic flooding and a generally higher level of moisture promote growth of plants not found elsewhere in the forest. Representative vegetation includes cottonwood, alder, aspen, and willow. Riparian zones are important for wildlife habitat, erosion control, flood control, ground water recharge, and water quality maintenance. The riparian zone extends down from the upper watershed and continues downstream from Lake Oroville to the mouth of the Feather. The riparian zone has been constricted over time by farming and land clearing, resulting in a narrow zone that generally only includes the streambanks and the areas between the levees.

The sagebrush steppe community is dominated by various sagebrush and perennial bunchgrass species. Bunchgrass dominance varies with soil depth and distribution. This community is found mainly in the eastern watershed area below the elevations of coniferous forests or at higher elevations where soils limit forest growth. This community has been substantially degraded by grazing in the past 100 years.

Land use in the study area includes timber harvesting, grazing, agriculture, recreation, mining, and hydroelectric development.

## Timber Harvesting

The North and Middle Fork Feather River watersheds provide favorable conditions for timber production. The area has considerable climatic and biologic variety resulting in a productive and extensive forest. The timber industry grew from a few sawmills in the 1850s to a major industry in the watershed but has declined significantly since the late 1980s. Timber harvesting occurs on both public and private land.

The U.S. Forest Service has managed the public's timber resources since its establishment in 1910. The Plumas National Forest has jurisdiction over a total of 1,828 square miles with 1,606 square miles in the study area. Plumas National Forest includes 53 percent of the North Fork Feather River watershed and 44 percent of the Middle Fork Feather River watershed. The PNF historic average for timber sold per year is 190 million board feet. In 1994, timber sold is expected to be approximately 60 million board feet, because of cuts in congressional funding and changing forest management policies (Taylor, 1994). Small portions of Lassen National Forest and Tahoe National Forest are also contained within the watershed study area but constitute a small percentage.

Private timber harvesting comprises significant land use in the watershed. The Collins Pine Company has access to a large block of private timberlands. For the past several years, annual production from the Collins' Almanor Forest has nearly equalled timber production of the national forest (DWR, 1988).

### Grazing

Montane Meadows and large valleys provide favorable range for livestock grazing and production. Grasses grow abundantly during the spring and near streams during the entire summer.

Horse, sheep, and cattle grazing began during the gold rush years. "The late 1800s and early 1900s saw intensive sheep grazing on the upland areas and high meadows, while intensive cattle grazing was occurring in the large meadows" (USFS, 1989). Many of the valley and streamside meadows are privately owned and are used for year-long livestock grazing.

The Plumas National Forest provides summer range for livestock operations during a 4.5 month period from June to mid-October using grazing permits. As of 1986, about 314,500 acres (27 percent) of the total 1,168,517 forest acres were classified as suitable for grazing activity. Of this available grazing land, about 71 percent was managed under a continuous grazing system, 27 percent was managed with a deferred system (grazing was deferred until plants reached seed maturity), and just 2 percent was managed with a rest-rotation system. During 1981, approximately 7,500 cattle and 1,400 sheep grazed on land in the Plumas National Forest (USFS, 1986). Similar figures are not available for private land and other National forest land constituting about 50 percent of the total watershed area.

### Agriculture

Agriculture is practiced on privately owned lands throughout the watershed but is concentrated on valley land. Flat valley lands contain deeper, more productive alluvial soils that are easier to cultivate and irrigate. Most irrigation diversion is for hay and pasture production. Sierra Valley, in the upper Middle Fork watershed, has large areas cultivated seasonally during the last 100 years. Alfalfa, winter wheat, oat, hay, and other forage types are the major crops grown. Within the Sacramento Valley, rice and fruit-nut orchards are the principal agricultural products along the Feather River.

### Recreation

For local economies, revenues from recreational activities have begun to rival those of other land use activities. The Feather River watershed offers mountains, lakes and streams. Recreational activities include fishing, hunting, hiking, bike riding, horseback riding, camping, nature photography and study, swimming, boating and water skiing, gold panning and dredging, off-road vehicle and snowmobile use, and cross-country skiing. There are many recreational facilities, both public and private. Recreation in Plumas National Forest has generally increased since the 1950s. Recreation visitor days were 2.3 million in 1982, which grew 12 percent to 2.6

million by 1992 (USFS, 1994). The USFS projects that recreation demand will increase at the current population growth rate in the region, reaching 4.6 million recreation visitor days by 2030 (USFS, 1986).

Lake recreation is available at numerous lakes, the most significant of which are Lake Almanor and Lake Oroville. Camping, boating, and fishing are the primary recreational pursuits.

Fishing and bird hunting are also important recreational opportunities along the lower Feather River. Some boating also occurs, but low flows during much of the year restrict usage.

## Mining

Mining in the watershed began in the mid-1800s and continues today, although on a smaller scale. Mineral resources include gold, copper, manganese, silver, chromite, lead, limestone, sand, gravel, and rock. The first miners exploited placer gold deposits in stream gravel. Gravel was dredged and sluiced to separate the gold. Between the 1850s and 1890s, hydraulic mining using high-pressure water jets to erode older gold-bearing formations, washed large amounts of sediment into the stream system.

Hard rock mining also produced large quantities of pulverized tailings. Many of these tailings now leach sulfides, which lower stream water pH. Sulfide contamination, by lowering pH, may significantly harm fisheries.

Dredging for placer gold occurred over large areas of what is now the Oroville Wildlife area. Windrows of gravel still remain although considerable gravel has been harvested for the construction of Oroville Dam and appurtenant facilities. Commercial gravel mining is also occurring in the area.

## Hydroelectric Development

The North Fork Feather River is extensively developed for hydroelectric power. About 720 megawatts are generated by Pacific Gas and Electric along the reach from Lake Almanor to Lake Oroville. The North Fork is advantageous for hydroelectric generation because of steep gradients, a large reservoir located high in the watershed, abundant snowfall, and high annual discharge.

PG&E regulates releases from Lake Almanor on the North Fork throughout the year. Downstream of Lake Almanor a series of impoundments divert streamflow through tunnels and penstocks to hydroelectric generators. The major hydropower storage reservoirs from upstream to downstream include Mountain Meadows Reservoir, Lake Almanor, Butt Valley Reservoir, Rock Creek and Cresta Reservoirs, and Bucks Lake (see Figure 9). Table 3 lists the PG&E powerhouses on the North Fork.

DWR has Antelope Lake, Frenchman Lake and Lake Davis but none of these have any hydroelectric development. Lake Oroville's Hyatt powerplant, the Thermalito diversion powerplant, and the Thermalito powerplant have a combined maximum generating capacity of about 850 megawatts.

**Pacific Gas and Electric's Hydroelectric Generating Plants on the North Fork Feather River (DWR, 1988)**

| HYDROELECTRIC GENERATING PLANTS | YEAR OPERATION BEGAN | FLOW AT NORMAL OPERATING CAPACITY (cfs) | NORMAL OPERATING CAPACITY (megawatts) |
|---|---|---|---|
| Hamilton Branch | 1921 | 200 | 4.8 |
| Butt Valley | 1958 | 1,620 | 40.0 |
| Caribou No. 1 | 1921 | 1,114 | 75.0 |
| Caribou No. 2 | 1958 | 1,464 | 120.0 |
| Belden | 1969 | 2,410 | 125.0 |
| Rock Creek | 1950 | 2,880 | 112.0 |
| Bucks Creek | 1928 | 340 | 57.5 |
| Cresta | 1949 | 3,510 | 70.0 |
| Poe | 1958 | 3,700 | 120.0 |
| Big Bend | 1909 | * | * |

* Big Bend generation plant was inundated by Lake Oroville in 1968.

## GEOLOGY

The watershed includes portions of the Cascade Range, Great Valley, and Sierra Nevada geomorphic provinces. Each province has unique geology and topography, reflecting fundamental differences in geologic history. Primary rock types in the watershed are granitic, volcanic, metamorphic, and sedimentary. The age of rocks range from Ordovician to Recent, with most being middle and late Mesozoic. The chief structural feature is the Foothills fault system, consisting of parallel faults oriented roughly southeast-northwest.

### Geologic Units

The Cascade Range province consists of volcanic rocks extending from Lake Almanor to British Columbia. The Cascade Range province comprises 495 square miles (15 percent) of the study area, from Lake Almanor to Lassen Peak. Cascade Range province rocks include tuff, breccia, volcanic ash, flows, and lahars of basaltic to rhyolitic composition, ranging in age from Pliocene to Recent.

The Sierra Nevada province abuts the Cascade Range province at Lake Almanor, extending southward about 400 miles to the Mojave Desert. This province occupies 2,810 square miles (85 percent) of the watershed. The Sierra Nevada province includes granitic intrusions, andesitic flows and breccia, basalt, metamorphic rocks, ultramafic rocks, and unconsolidated sedimentary deposits. Cascade Range rocks also occur as the erosional remnants of a thick blanket of volcanic rocks that formerly covered much of the watershed. Uplift of the Sierra Nevada province, by various mechanisms starting in the early Cenozoic, continue today. The current uplift mechanism which stems from mantle-thinning, commenced approximately five million years ago in the Pliocene epoch (Unruh, 1991).

Ultramafic Mesozoic rocks consist largely of serpentinite but also include peridotite, pyroxinite and talc schist. Serpentinite is a moderately soft, green alteration product of ultramafic igneous rock prominent in the central portion of the watershed. It is generally associated with fault zones. An almost continuous band about 3 miles wide crosses the watershed from northwest to southeast. These rocks are structurally weak and landslide-prone.

Jurassic and Cretaceous granitic rocks were emplaced by stoping and shouldering aside overlying rock, forming roughly circular patterns, ranging from less than five miles to over twenty miles in diameter. In the western portion of the watershed, they are bounded by metamorphic rock; in the eastern portion they are partially covered by volcanic flows. Granitic rocks include granite, granodiorite, diorite, and gabbro. Highly weathered or decomposed granite is erodible and prone to landslides and occurs in the eastern watershed and along portions of the North Fork Feather River.

Metamorphic rocks ranging in age from Ordovician to Cretaceous underlie a significant portion of the watershed. These are generally greenschist facies metamorphic rocks occurring along northwest trending belts or in contact areols surrounding intruding plutons. Argillite, slate, mica schist, graywacke, quartzite, and marble were derived from sedimentary rocks. Greenstone, amphibolite, talc schist, and chlorite schist were derived from igneous rocks, or sedimentary rocks derived from igneous rocks. These thin-bedded, foliated and steeply dipping rocks are extensively folded and faulted. Some of these rocks belong to the Smartville Ophiolite Complex. Some of these rocks are often structurally weak and subject to landslides.

Sedimentary deposits include Tertiary gold-bearing or "auriferous" gravels, glacial till, Quaternary alluvium, and landslide deposits. Tertiary auriferous gravels are stream deposits buried by volcanic activity such as flows and lahars during the Eocene and later. The auriferous gravels range from sand-size to boulder-size and contain placer gold. Where exposed by hydraulic mining, these deposits are erodible and landslide prone.

Glacial till forms small moraines at the base of glacial cirques such as those on the slopes of Mt. Lassen. Glacial till deposits are also found in the southern portion of the watershed. Quaternary alluvium occurs along active stream channels, on floodplains and on valley floors. Most of the deposits occur in the broad, fault bounded valleys in the eastern portion of the watershed. The loose, unconsolidated sand, silt and gravel deposits can be highly erodible where it is exposed on steep slopes in gullies, headcuts, and streambanks.

Landslides occur in a variety of rock types. Large landslides are common around Lake Oroville and along the North Fork Feather River, mostly in metamorphic rocks. Landslides also occur along the Middle Fork Feather. The combination of steep topography and steeply dipping, highly faulted, thin-bedded and weakly metamorphosed sediments in a seismically active area indicates a potential landslide risk. This potential risk ranges from minor rockfalls to destructive landslides. Evidence indicates a historic landslide temporarily blocked the North Fork of the Feather River (DWR, 1979). Landslides in the vicinity of Lake Oroville are discussed in more detail further in the report.

Deposits in the Sacramento Valley proper are only a small fraction of the overall watershed area. It mostly includes a narrow strip along the Feather River between Oroville and Verona. The deposits are older Tertiary sedimentary deposits, terrace deposits, basin deposits, and more recent stream-derived channel and floodplain deposits.

## Geologic Structure and Seismicity

Geologic structure in the North Fork and Middle Fork Feather River watershed contributes significantly to slope instability and erosion (DWR, 1979). Historic seismicity within and adjoining the watershed is fairly low. Structures include faults, folds, bedding, and foliation.

Two fault types offset rocks in the watershed: High-angle reverse faults in the Sierra Nevada province and normal faults in the Sierra Nevada and Cascade province.

The dominant structure of the Sierra Nevada metamorphic belt is a series of north to northwest-trending, east-dipping reverse faults, called the foothills fault system. These faults were formed during accretion of oceanic, crustal, and island-arc rocks during the late Jurassic Nevadan orogeny (Schweickert and Cowan, 1975). Seismicity on these faults has been reactivated in the late Cenozoic (Wong, 1992).  Historic seismicity in the foothills fault system include a magnitude 5.7 on August 1, 1975, southeast of Oroville; a magnitude 4.6 on May 24, 1966, near Chico; and a magnitude 5.7 on February 8, 1940, 20 miles east of Chico.  Faults also occur in the Sierran Basement below the valley floor.  The two most seismically active of these are the Willows fault in the center of the valley and the Great Valley fault along the valley's western edge.

In the eastern portion of the watershed, the dominant structural feature is a series of roughly parallel normal faults, resulting from extentional tectonic forces.  This structural regime is related to the adjacent Basin and Range province, which adjoins the Honey Lake Escarpment on the east.  Displacement along these faults has created a series of down-dropped broad alluvial valleys bounded by ridges.

Normal faulting is responsible for current seismicity in the eastern watershed area.  The greatest magnitude historic seismic event in this area occurred on an unnamed fault near Portola at a magnitude 5.6 in 1959 (DWR, 1993).

Folding is chiefly limited to metamorphic rocks within the Sierra Nevada province with predominant isoclinal folds and overturned relict beds.  In general, metamorphic rocks "...  dip steeply eastward and form a stack of west-directed thrust sheets."  (Hacker, 1993).  Folding originated during a succession of deformational events including the late Jurassic Nevadan orogeny in which island arc and arc-trench deposits were accreted to the ancestral north American continent (Schweickert and Cowan, 1975).

Foliation occurs over large portions of the metamorphic rock terrain in the Sierra Nevada province.  Foliation is the planar orientation of platy minerals, formed by heating and tectonic compression of rocks.  Foliation in these rocks appears as slaty cleavage, oriented southeast-northwest, roughly parallel to the Sierra Nevada crest.  Foliation is most pronounced in metamorphosed rocks of sedimentary origin whereas foliation is less common in rocks of volcanic or plutonic origin.

## HYDROLOGY

Natural watershed systems exist in dynamic equilibrium. All the components of a fluvial system such as flow, gradient, channel length, width, and depth, channel bedforms, and floodplains evolve together. These components control the erosion rate, sediment transport, and depositional patterns. Equilibrium may be upset by various land use practices such as cattle grazing, road construction and timber harvesting, or channel modifications such as dams and diversions. Small changes in one place along a stream may have larger effects elsewhere as the hydrologic forces attempt to return to an equilibrium state.

Prior to land and water uses that began in the 1850s, runoff flowed unchecked across mountain meadows and down canyon channels onto the floor of the Sacramento Valley. High flows from winter rain and spring snowmelt sharply contrasted with the low base flows of summer and fall. In the upper watershed where gradients are comparatively gentle, mountain meadows were heavily vegetated and streams followed a meandering pattern. Meadows became floodplains and temporary storage reservoirs, reducing peak flows downstream and reducing the stream's capacity to transport large amounts of sediment. This promoted sediment deposition, groundwater infiltration, and meadow productivity.

The broad alluvial valleys, bounded by volcanic ridges in the eastern topographic area, are considerably altered from their pristine condition. In 1934, John E. Hughes, Junior Forester, Plumas National Forest, described the condition of natural meadow-stream systems (SCS, 1991). "Originally the meadows were well watered by meandering streams whose courses were often concealed by thick vegetation. The streams ran through numerous deep pools covered by lily pads; and in the spring, water stood over practically the entire area of many of the meadows, while the water table was high, even in summer, because the drainage channels were shallow."

After 140 years of water resource development and intensive land use in the watershed, the natural hydrology has been substantially altered. This is evident in the accelerated erosion rates, stream bank degradation, loss of riparian vegetation, head-cutting and gully formation, de-watered aquifers, and sedimentation in downstream reservoirs. This is particularly apparent and well documented in the eastern portion of the North Fork Feather River watershed (DWR, 1990; USFS, 1988; USFS, 1991; USFS, 1992; SCS,1989; SCS, 1991; PGE, 1986). Reservoirs such as Lake Almanor and Lake Oroville, in turn, have reduced floodflows downstream and in the valley below.

Streams downstream of reservoirs are also affected. Hydraulic alteration, primarily caused by the attenuation of peak flows, increased summer flows, and diversions, affect stream processes such as sediment transport, riffle-pool-run ratios, riparian vegetation, bar development, bank erosion, and others. Sediment is trapped in reservoirs, resulting in sediment starvation in the streams below the dam.

### Water Resources Development

There are numerous reservoirs in the watershed. Most are owned and operated by PG&E and the Department of Water Resources. The table below shows the dams of jurisdictional size.

**Dams in North Fork, West Branch, South Fork, and Middle Fork Feather River Watershed Within Jurisdiction of the State of California**

| Name of Dam (Reservoir) | Name of Stream (Watershed) | Drainage Area (Sq. Mi.) | Reservoir Area (Acres) | Storage Capacity (Ac-Ft) | Crest Elevation (Ft) | Year Completed |
|---|---|---|---|---|---|---|
| Antelope | Indian Creek (EBNFFR) | 71 | 890 | 21,600 | 5,025 | 1964 |
| Bidwell Lake (Round Valley Reservoir) | North Canyon Creek (EBNFFR) | 9.12 | 400 | 4,800 | 4,495.6 | 1865 |
| Bucks Diversion | Bucks (NFFR) | 30.6 | 136 | 5,843 | 5,039.5 | 1928 |
| Bucks Storage (Bucks Lake) | Bucks Creek (NFFR) | 28 | 1,827 | 103,000 | 5,178.5 | 1928 |
| Butt Valley | Butt Creek (NFFR) | 75 | 1,600 | 53,120 | 4,144 | 1924 |
| Caribou Afterbay | North Fork Feather River | 616 | 42 | 3,400 | 2,985 | 1959 |
| Chester Diversion | North Fork Feather River | 113 | 15 | 75 | 4,610 | 1975 |
| Cresta | North Fork Feather River | 1,872 | 62 | 4,400 | 1,680 | 1949 |
| Eureka Lake | Eureka Creek (MFFR) | 0.64 | 42 | 400 | 6,200 | 1866 |
| Frenchman | Little Last Chance Creek (MFFR) | 82 | 1,470 | 51,000 | 5,607 | 1961 |
| Grizzly Creek | Grizzly Creek (NFFR) | 50.5 | 11 | 140 | 5,054 | Unknown |
| Grizzly Forebay | Grizzly Creek (NFFR) | 12.6 | 38 | 1,112 | 4,337.8 | 1928 |
| Grizzly Valley (Lake Davis) | Big Grizzly Creek (MFFR) | 44 | 4,000 | 83,000 | 5,785 | 1966 |
| Lake Almanor | North Fork Feather River | 503 | 28,257 | 442,000 | 4,515 | 1927 |
| Long Lake | Gray Eagle Creek (MFFR) | 1.13 | 141 | 1,478 | 6,531 | 1938 |
| Lower Three Lakes (Three Lakes) | Milk Ranch (NFFR) | 1.5 | 44 | 606 | 6,084 | 1928 |
| Rock Creek | North Fork Feather River | 1,700 | 80 | 4,660 | 2,220 | 1950 |
| Silver Lake | Silver Creek (EBNFFR) | 1 | 120 | 650 | 6,000 | 1906 |

| Name of Dam (Reservoir) | Name of Stream (Watershed) | Drainage Area (Sq. Mi.) | Reservoir Area (Acres) | Storage Capacity (Ac-Ft) | Crest Elevation (Ft) | Year Completed |
|---|---|---|---|---|---|---|
| Spring Valley Lake | Rock Creek (NFFR) | .25 | 15 | 75 | 6,314 | Unknown |
| Taylor Lake | Tributary to Indian Creek (EBNFFR) | .36 | 36 | 380 | 7,000 | 1929 |
| Indian Ole (Mt. Meadows Res.) | Hamilton Creek (NFFR) | 158 | 5,800 | 24,800 | 5,045.7 | 1924 |
| Westwood Mill Pond | Robbers Creek (NFFR) | 40 | 112 | 660 | 5,074 | 1914 |
| Feather R. Hatchery | Feather River | 3,640 | 52 | 580 | 181 | 1964 |
| Lake Madrone | Berry Creek (NFFR) | 14.9 | 25 | 200 | 1,985.5 | 1931 |
| Oroville | Feather River | 3,611 | 15,500 | 3,484,000 | 922 | 1968 |
| Poe | Feather River | 1,950 | 52 | 1,150 | 1,390 | 1958 |
| Round Valley | North Fork Feather River | 2.17 | 90 | 1,285 | 5,498 | 1877 |
| Thermalito Afterbay | Tributary Feather River | 13.3 | 4,550 | 57,500 | 142 | 1967 |
| Thermalito Diversion | Feather River | 3,640 | 330 | 13,400 | 233 | 1967 |
| Palen | Antelope Creek (MFFR) | 10.6 | 12 | 146 | 5,030 | 1951 |

Add South Fork and West Branch

## Stream Discharge

The largest flows occur during the winter in response to rain, and in the spring and early summer in response to snowmelt. The lowest flows occur during late summer and early fall. The combined North and Middle Fork mean discharge to Lake Oroville is approximately 7,555 acre-feet per day, or 2.76 million acre-feet per year. Total average yearly yield to Lake Oroville is 6284 cfs for the 1969 to 2000 water years.

Table 5 is a list of gaging stations. Stations were chosen to represent flows of major rivers and tributaries coming into Lake Oroville.

All USGS gaging stations on the Middle Fork and its tributaries have been discontinued but there are 19 active USGS gaging stations on the North Fork and its tributaries. The lack of streamflow data on the Middle Fork is likely attributable to difficult access and the absence of hydroelectric generation.

Average monthly flows for the period of record are presented for the North Fork, Middle Fork, South Fork, and for gaging stations below Lake Oroville.

**Table of USGS Stream Gaging Station Data***

| USGS Station Number | Station Name | Period of Record | Drainage Area ($mi^2$) | Average Discharge (cfs) | Elevation above datum(ft) |
|---|---|---|---|---|---|
| 11399500 | Feather River, North Fork, near Prattville | 1906-1991 | 493 | 401 | 4,390 |
| | | | | | |
| | | | | | |
| | | | | | |
| 11404900 | Feather River, North Fork, below Poe Dam, near Jarbo Gap | 1967-1991 | 1,942 | 2,325 | 1,306 |
| 11392500 | Feather River, Middle Fork, near Chico | 1925-1979 | 686 | 283 | 4,380 |
| 11394500 | Feather River, Middle Fork, near Merrimac | 1951-1986 | 1,062 | 1,484 | 1,560 |

*Information was tabulated from U. S. Geological Survey's daily values (1991)

**Yearly and Mean Monthly Streamflow below Lake Oroville**

Gaging stations useful for geomorphic analyses of the lower Feather River are shown in the following table.

TABLE OF GAGING STATIONS

| GAGE NAME | NUMBER | PERIOD OF RECORD | MEAN FLOW CFS | AREA SQ. MI |
|---|---|---|---|---|
| Lake Oroville near Oroville | **11406800** | **Nov. 1967-** | | 3,607 |
| Sum of diversions | **na** | **Nov. 1967-** | **1,100** | na |
| Feather River at Oroville | **11407000** | **Oct. 1901-** | **6,280*** | 3,624 |
| Feather River near Gridley | **11407150** | **Oct 1964- 1998** | **4,852** | 3,676 |
| Feather River at Yuba City | **11407700** | **Oct 1964- 1984** | **5,812** | 3,974 |
| Feather River near Nicolaus | 11425000 | Apr. 1942- 1983 | 8,140 | 5,921 |

* Adjusted yield for evaporation from Lake Oroville and diversions, 1902-2000. Annual yield from 1902 to 1967 is 5830 cfs; from 1967 to 2000 is 1140 cfs.

The Lake Oroville gage shows storage and lake level. It is useful for determining impacts on the streams draining into Lake Oroville and shoreline impacts.

The Feather River at Oroville gage is downstream of the Thermalito Diversion Dam. From 1901 to 1967, the gage recorded flows characteristic of pre- dam conditions. The annual mean flow was 5,830 cfs. After 1967, much of the flow was diverted to the Thermalito Afterbay. During most of the year, flows averaging between 500 and 600 cfs occur in the low flow section of the river between the Thermalito Diversion Dam and the Thermalito Afterbay discharge to the Feather River. The annual mean in the low flow section of the river is 1140 cfs using 1967 to 2000 water years. The pre- and post Oroville Dam mean monthly streamflow for this gage is shown in the figure below. This gage best reflects flow conditions in the low flow section between the Thermalito Diversion dam and the Thermalito Outfall.

There are five diversions from Lake Oroville and Thermalito. These are the Palermo Canal (11406810) with an annual mean flow of 10.5 cfs, the Western Canal (11406880) with an average annual mean flow of 320 cfs, the Richvale Canal (11406890) with a flow of 127 cfs, the Pacific Gas and Electric Co. Lateral Intake (11406900) with a flow of 5 cfs, and the Sutter-Butte Canal (11406910) with a flow of 644 cfs. The average combined annual diversion from these is about 1,100 cfs. This is about 20 percent of the average annual yield of the Feather River at this point. July has the highest diversion, with the combined diversion averaging 2600 cfs (1967-98). The sum of these five mean monthly average diversions is shown in the figure below.

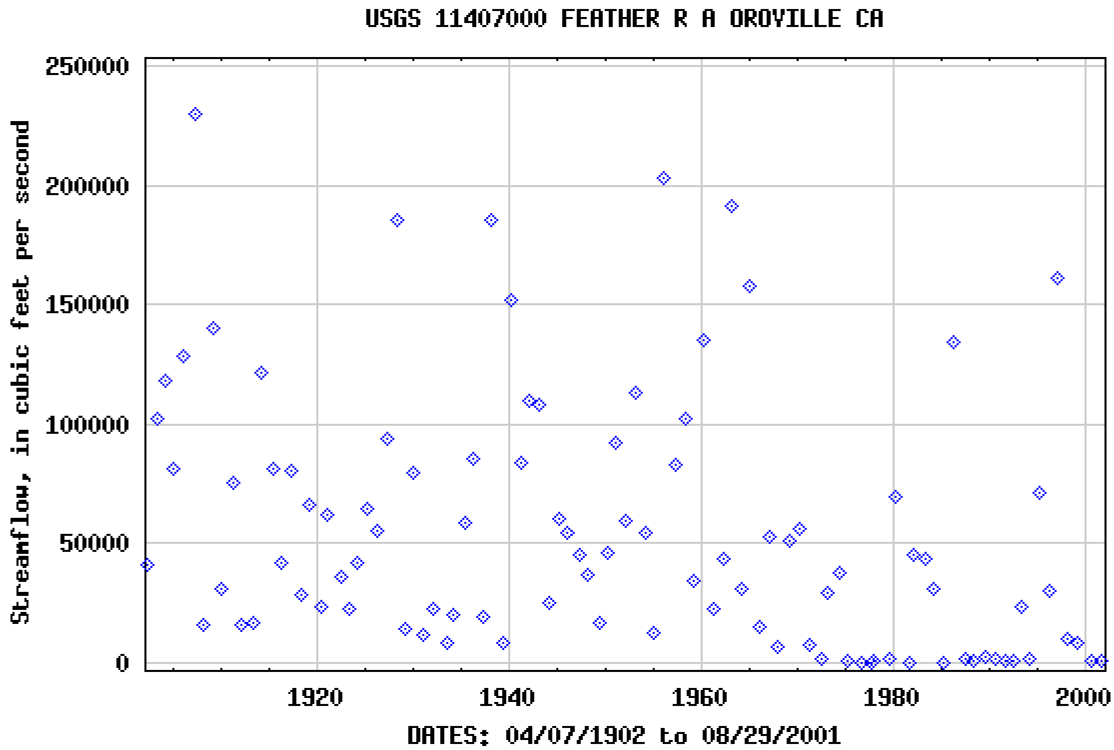
The Feather River near Gridley gage is about 300 feet upstream of the highway bridge and three miles east of Gridley. The record begins in 1964 and ends in 1998. No tributaries occur between the Oroville gage and Gridley, but the station reflects diversions made upstream. The pre- and post dam changes in mean monthly discharge is shown in the figure below. The Gridley station best represents flows in the Feather River between the Thermalito outfall and the mouth of Honcut Creek.

The Feather River at Yuba City gage has a limited record that is not as long as the Gridley and Nicolaus gages. The average annual yields are therefore not strictly comparable. However, it does include flow from Honcut Creek and is the best gage to represent flows in the Feather River between the mouth of Honcut Creek and the mouth of the Yuba River.

The Feather River near Nicolaus gage is on the left bank 1.7 miles southwest of Nicolaus. It includes the drainages of the Yuba and Bear rivers. The gage best describes flow conditions on the Feather between the mouth of the Bear River (RM 12.3) and the mouth of the Feather at Verona. The gage ceased operation in 1983 after about 40 years of record.

## Peak Flows

Peak flows were available for all the stream gages downstream of Lake Oroville. However, the periods of record differed for each station. The Feather River at Oroville gage has the longest period of record. The graph below, derived from the U.S. Geological Survey website, shows the peak daily flood flows for this gage. The following table shows the peak daily flow for flood years. Years without flood flows are not shown.



HIGHEST PEAK DAILY FLOOD FLOW FOR FLOOD YEARS
FEATHER RIVER STREAM GAGES BELOW LAKE OROVILLE
IN 1,000'S OF CFS

| | **GAGING** | | **STATIONS** | | |
|---|---|---|---|---|---|
| CALENDAR YEAR | **Oroville * 11407000** | **Gridley 11407150** | **Yuba City 11407700** | **Olivehurst 11421700** | Nicolaus 11425000 |
| 1903 | **102** | **-** | **-** | **-** | - |
| 1904 | **118** | **-** | **-** | **-** | - |
| 1906 | **128** | **-** | **-** | **-** | - |
| 1907 | **230** | **-** | **-** | **-** | - |
| 1909 | **140** | **-** | **-** | **-** | - |
| 1913 | **122** | **-** | **-** | **-** | - |
| 1928 | **185** | **-** | **-** | **-** | - |
| 1937 | **185** | **-** | **-** | **-** | - |
| 1940 | **152** | **-** | **-** | **-** | - |
| 1942 | **110** | **-** | **-** | **-** | - |
| 1943 | **108** | **-** | **-** | **-** | - |
| 1953 | **113** | **-** | **-** | **-** | 127 |
| 1955 | **203** | **-** | **-** | **-** | 357 |
| 1958 | **102** | **-** | **-** | **-** | - |
| 1960 | **135** | **-** | **-** | **-** | 136 |
| 1963 | **191** | **-** | **-** | **-** | 264 |
| 1964 | **158** | **151** | **182** | **-** | 281 |
| 1967 | **53.3** | **45.6** | **52.8** | **-** | 96.6 |
| 1969 | **51.1** | **56.4** | **48.1** | **-** | 88.4 |
| 1970 | **56.3** | **72.9** | **74.5** | **133** | 146 |
| 1973 | **29.7** | **47** | **54.6** | **62.1** | 72 |
| 1974 | **37.8** | **54.7** | **55.3** | **88** | 108 |
| 1980 | **69.5** | **90.1** | **-** | **105** | 115 |
| 1981 | **45** | **61.8** | **-** | **-** | 148 |
| 1983 | **43.5** | **60** | **-** | **-** | 112 |
| 1986 | **134** | **150** | **-** | **-** | - |
| 1993 | **23.4** | **37.7** | **-** | **-** | - |
| 1995 | **71.7** | **89.4** | **-** | **-** | - |
| 1996 | **30.2** | **45.7** | **-** | **-** | - |
| 1997 | **161** | **163** | **-** | **-** | - |
| 1998 | **10.2** | **26.4** | **-** | **-** | - |

NOTE: Calendar years;
 - No data;
* 1901- 1967 Pre-Oroville Project minimum flood flow recorded in table is 100,000 cfs; 1967-Post Oroville Project minimum flood flow recorded is 10,000 cfs.

## CHANNEL MORPHOLOGY

Stream length from the headwaters to Oroville Dam is approximately 135 miles along the North Fork and 120 miles along the Middle Fork Feather River (Figures 7 and 8). The complex topography governs stream morphology. Stream gradients are moderate in the upper portions of the watershed where streams cross montane meadows and valleys. Gradients increase as streams flow through deep, rugged canyons.

North Fork Feather River watershed has an area of 2,006 square miles and the Middle Fork 1,216 square miles.The channel morphologies are different and will be discussed separately.

### North Fork Feather River

Elevations range from 10,000 feet on the southeast slope of Mt. Lassen, and drops to a minimum elevation of 900 feet at Lake Oroville. The upper portion has a number of basins with a mix of dense timber and montane meadows. The largest of these, about 39 square miles, was called Big Meadows until inundated by Lake Almanor.

The main channel between Lake Almanor and Lake Oroville flows through steep canyons. The elevation drop of nearly 4,000 feet is fairly evenly distributed over the 65-mile distance. The form, slope, and behavior of this mostly bedrock channel are determined more by its geology than the quantity of water and sediment which it conveys (DWR, 1988). The channel has a pool-riffle configuration.

Four dams have been built in this reach for hydroelectric production. The high precipitation, large impoundment capabilities Lake Almanor, and the steep canyon below are major reasons for the extensive hydroelectric development.

The East Branch of the North Fork (1,031 square miles) is a major tributary and drains the eastern part of the North Fork's watershed, from the Honey Lake Escarpment to its confluence with the North Fork Feather River near Belden on Highway 70. DWR's Antelope Lake is on Indian Creek, one of the East Branch tributaries. The East Branch has been identified as a major contributor of sediment, mainly because of differences in geology and soils, and extensive timber harvesting and grazing (PGE, 1986; SCS, 1989).

Sources of bedload material have been the East Branch, other tributaries, and bank erosion since the construction of Lake Almanor in 1913. Large quantities of sand and silt enter the North Fork from the East Branch. These sediments accumulate in pools, on point bars, and behind dams (DWR, 1988). Reservoirs such as Rock Creek and Cresta on the North Fork trap most of the gravel-size and some of the sand- and silt-size sediment. According to a PG&E survey (1992), 4.4 million cubic yards of sediment have been deposited behind Rock Creek Dam in 34 years. This rate of deposition averages approximately 130,000 cubic yards per year. Typical of dammed rivers, stream channels below the reservoirs have become depleted in gravel and sand sizes and armored by cobbles and boulders.

## West Branch Feather River

The West Branch………………………………

## Middle Fork Feather River

The Middle Fork is approximately 108 miles long from its headwaters to Lake Oroville. The maximum elevation in the Middle Fork watershed is approximately 7,500 feet in the mountains bordering Sierra Valley, dropping to a minimum elevation of 900 feet at Lake Oroville. Channel gradient is low to moderate in the upper basin. Gradient increases dramatically in the lower reaches as the river flows through rugged, steep canyons. The Middle Fork became part of the National Wild and Scenic Rivers System in October 1968.

Sierra Valley is a 203 square mile valley, mostly developed for agriculture, in the upper part of the watershed. It is the largest valley in the study area. The valley is relatively flat and interwoven with a meandering, twisting pattern of creeks, irrigation ditches, and diversion channels. The main crop is alfalfa, but the valley is also used for dryland farming, grazing, irrigated crops, and pasture.

Unlike the North Fork, the Middle Fork has no system of hydroelectric projects upstream of Lake Oroville. Frenchman Lake and Lake Davis are the only major reservoirs and were constructed on tributaries as part of the State Water Project in the 1960s. Lake Davis was built to provide public recreation, enhance downstream fisheries and supply water for the city of Portola. Frenchman Reservoir provides reservoir recreation and irrigation water for Sierra Valley.

Downstream from the community of Sloat, the Middle Fork becomes a wild river as it flows approximately 45 miles through the Middle Fork Canyon. In places, the sides of the gorge rise one-half mile straight up from the gravel banks of the river. An average stream gradient of 62 feet per mile through this section has created numerous pools and riffles. The Middle Fork Feather River provides excellent habitat and is considered one of the best wild trout fisheries in California.

Little data has been compiled on erosion and sedimentation. Most erosion investigations have been conducted on the East Branch of the North Fork. With the lack of hydroelectric development, little incentive exists to gather information on flows, erosion or sedimentation. Streamflow data collection was discontinued at all United States Geological Survey (USGS) gaging stations by 1986. Conclusions about erosion and sedimentation in the Middle Fork Feather River watershed must be based on the minimal information available and comparisons to similar situations on the North Fork.

The Middle Fork watershed shares many characteristics with the North Fork including land use practices, precipitation patterns, vegetation, topography, and geology. Because of these similarities, watershed erosion and sediment transport rates are probably similar to those occurring in the North Fork watershed. Unlike the North Fork with numerous dams, diversions and power plants, sediment from the Middle Fork is not trapped by dams until arriving at Lake Oroville.

## South Fork Feather River

The South Fork watershed………………………………………………..

## Feather River below Lake Oroville

## INSTABILITY AND EROSION HAZARD

Past watershed instability, erosion, and sedimentation investigations have focused largely on tributaries of the North Fork with little attention to the Middle Fork watershed. This focus on the North Fork and its tributaries reflects concern over excessive sedimentation and increased maintenance effectively reducing the operating efficiency and life span of reservoirs and power plants. Landslides cause increased sedimentation and downstream cumulative effects. Erosion and downcutting of streams lowers groundwater levels and dewaters meadows. Reduced stream flow in the late summer and fall from dewatered meadows reduces hydropower generation capability. The dewatering of meadows has also resulted in a transformation from perennial grasses to dryland vegetation such as sagebrush.

### Instability

Landslides are a major source of sediment in the watershed. The western portion of the watershed is most sensitive to this hazard, particularly the canyons of the Feather River and canyons of Indian, Spanish, and Eureka creeks (USFS, 1986). Pre-historic landslides large enough to temporarily block the North Fork may have occurred. No basinwide landslide investigation has been done in the Feather River drainage.

A 30,000 cubic yard landslide damaged two PG&E hydroelectric powerhouses and related equipment costing $40 million to repair (Sacramento Bee, February 26, 1985). The landslide occurred at the Caribou powerhouse and Belden Reservoir on the North Fork Feather River.

Numerous landslides occur along the Feather River and its major forks. Failures in this watershed are largely within volcanic and metamorphic lithologies. The toes of a number of these landslides are now seasonally inundated by Lake Oroville. Landslide movements are mostly prehistoric. However, several failures indicate recent activity (DWR, 1979). A large "dormant" landslide (approximately three square miles) is on the north slope of Bloomer Hill, directly above the North Fork in the Lake Oroville reservoir. The toe has recently been reactivated in places. Catastrophic movement of this landslide is a public policy concern because of its potential disastrous effect on the Lake Oroville.

Rock units with a history of slope instability in the watershed are the metamorphic "greenstone" belt on Quincy road, serpentinite and talc schist, Tertiary non-marine gravel, and Tertiary pyroclastic rocks, especially those with high clay contents (USFS, 1988).

### Erosion Hazard

The greatest erosion effects occur on the East Branch of the North Fork Feather River. The deteriorating condition is evident with gully formation and channel down-cutting occurring on a large scale in the broad alluvial valleys in the upper part of the watershed.

Table 6 presents sediment data from subwatersheds within the East Branch watershed. The subwatersheds are shown in Figure 11. These data were obtained from the Soil Conservation Service report *East Branch North Fork Feather River Erosion Inventory Report* (1989), written in cooperation with the Feather River Coordinated Resource Management Group.

**Table 6**

**Sediment Yield to Rock Creek Reservoir (SCS, 1989)***

| Subwatershed Number | Subwatershed Name | Tons per Sq. Mile |
|---|---|---|
| 12 | Above Antelope Lake | 2,120 |
| 3 | N.F. Feather River | 1,760 |
| 9 | Wolf-Round Valley | 1,650 |
| 5 | Upper Spanish-Rock | 1,300 |
| 6 | Lower Spanish | 1,160 |
| 13 | Last Chance | 1,110 |
| 11 | Hungary-Mid. Indian | 1,110 |
| 7 | Greenhorn | 1,050 |
| 15 | Red-Clover Dixie | 830 |
| 8 | Little Grizzly | 770 |
| 4 | Rush-Mill | 760 |
| 10 | Lights-Cooks | 730 |
| 14 | Squaw Queen | 660 |
| 1 | Chips-Yellow | 610 |
| 2 | Butt Valley Res. | 0 |

* Subwatersheds are ranked in descending order of sediment yield in tons per square mile. Subwatershed numbers provide locations on Figure 11.

## Instability and Erosion Hazard Mapping

The watershed within the Plumas National Forest has been mapped and ranked for erosion hazards by USFS for planning purposes. Department of Water Resources obtained the information from USFS and used it to prepare the Erosion Hazard Map (Plate 1, in back pocket).

Plate 1 shows the potential for erosion hazard and landslide activity in the Plumas National Forest part of the watershed.  Two land stability risk classifications used by Plumas National Forest, Low Risk and Moderate Risk, were combined as Class I, Low to Moderate Risk.  Class I typically represents gentle to moderately steep (<60%) sloped lands with few signs of naturally caused slope instability.   Class II, High Risk, represents steep slopes with visible signs of naturally caused slope instability.  Class III, Extreme Risk, represents lands that are usually very steep (>75%) and show evidence of recent landslide occurrence.

Risk areas were digitized from Plumas National Forest data using an Autocad computer program. The resources used by the USFS contractors to compile the original Risk Maps at 1:24,000 scale include:  1) slide feature maps from aerial photo interpretation; 2) slope maps, geologic maps, soils maps, aerial photos, and site specific landslide information from existing engineering geology reports, and; 3) personal observations of USFS personnel.  The classification system used in the enclosed Erosion Hazard Map is in Appendix B.

The streambank erosion information was obtained from a Soil Conservation Service report, *East Branch North Fork Feather River Erosion Inventory Report* (SCS, 1989).  The area covered by that report includes all of the East Branch and three other subwatersheds of the North Fork Feather River, as shown on Figure 11.   Streams, with sediment production of 600 tons per square mile or more, were highlighted.

The Instability and Erosion Hazard Map is only complete for the 50 percent of the study area in Plumas National Forest.  Minimal data exist in parts in Lassen and Tahoe National Forests or on private land.  The larger unmapped areas are identified on Plate 1.

Instability and Erosion Hazard for the Lake Oroville Area

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